November 1977

USDA FOREST SERVICE
RESEARCH NOTE RM-349

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Aquatic Inhabitants of a Mine Waste Stream in Arizona[1]

Michael Lewis[2]

Abstract

Changes in biotic composition and water quality in a copper mine waste stream were monitored before and after a large discharge of waste altered stream geomorphology and water quality. Initially, water quality and biotic composition in the waste stream were similar to those in a "control" stream; however, after the waste influx, biotic diversity was reduced and water quality was degraded.

Keywords: Water quality, aquatic habitat.

Arizona's copper mines require approximately 380,000 liters of water to process one ton of copper. The liquid wastes, which are often enriched with processing chemicals, metals, and suspended solids after passing through the refinement process, are stored in tailings ponds either for water storage, settling of suspended ore tailings, or control of discharges into public waters. Wastes as a result of seepage or discharge from such ponds often flow through flumes or natural drainages into nearby streams. Flow in these "waste streams" may be more constant than the natural flow in the receiving stream, which in Arizona is usually ephemeral or intermittent. Therefore, these waste streams, despite a degraded quality, may be capable of supporting aquatic organisms that are dependent upon a reliable surface flow for survival.

This Note reports the biotic composition of a waste stream, and changes in that composition due to an unusually large effluent release that had a degrading effect on the habitat.

[1]The research reported here is a contribution of the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements.

[2]Department of Zoology, Arizona State University, Tempe, Arizona. Administrative supervision was provided by Earl F. Aldon, project leader, Mine Spoil Reclamation in the Southwest, Rocky Mountain Forest and Range Experiment Station, Albuquerque, in cooperation with University of New Mexico. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

Streams studied

The 1.87 km discharge channel studied conveyed effluents from a Pinto Valley Mine tailings pond into intermittent Pinto Creek (fig. 1). The mine and stream (33° 25' N; 111° 00' W) are located approximately 16 km west of Miami, Ariz. on the southeastern corner of the Tonto National Forest. The unshaded discharge channel flows through an area of crystalline intrusive rocks bordered by chapparal. Initially, the gravel-bottomed riffles alternated with pools with fine-grained bottoms. The stream was inundated, however, with an unusually large amount of ore tailings and waste water when the tailings pond dam ruptured in May 1975. The biotic composition and stream physiography were altered as a result.

Five sampling stations had been established 3 months prior to the dam rupture to determine biotic composition (fig. 1). Stations 1, 2, and 3, with a mean gradient of 5.25 cm/m, were located within 0.4 km of the tailings dam, while Stations 4 and 5, with a mean gradient of 0.75 cm/m, were located 1.3 km below the dam. All stations were affected by the effluents, and no control area in the stream could be established. As a result, the only reasonable basis of comparison was between the biota in the waste stream and that in Pinto Creek above their confluence.

Methods

The biota were sampled bimonthly at each sampling station from January 1975 to September 1976. Physiochemical observations were begun in January 1975. A pool and riffle area at each station in the discharge channel and Pinto Creek were qualitatively sampled for macroinvertebrates with a 4-mm mesh dip net and a Surber sampler[3] ($0.09 m^2$). Only qualitative evaluations are presented due to the difficulty of sampling the thick tailings cover over the substrate that persisted for most of the study. All macroscopic surface and clinging insects were brushed from rocks and benthic vegetation for preservation and later identification.

Fish were collected with portable shocking equipment and 6-mm mesh seines. The longfin dace, *Agosia chrysogaster,* was found to be the only existent species of fish in January 1975. A Petersen population estimate for the species was

[3] *The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

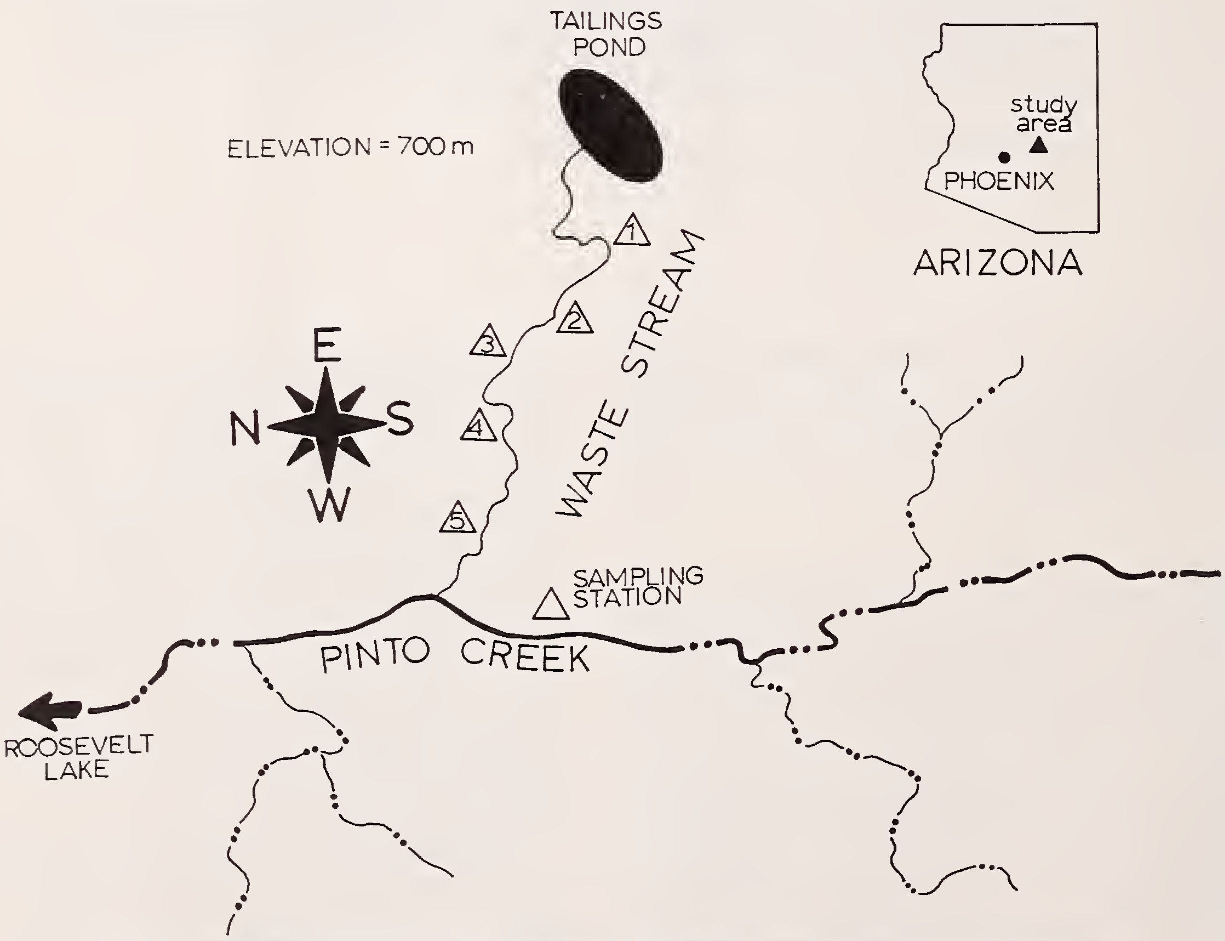


Figure 1.—Map location of the copper mine waste stream and sampling stations.

conducted during February 1975; two recovery periods were attempted within 1 month after clipping left pelvic fins.

Water samples were collected bimonthly at Station 5 and water quality was analyzed by the State Bureau of Water Quality Control. Chemical analyses, except metal content, followed procedures outlined in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 1971). Metal content (total soluble metal) was determined with a flame spectrophotometer. Additional water samples taken monthly at Stations 1, 2, 3, and 4 were analyzed in the field for pH, hardness, copper, and iron using a Hach kit. Dissolved oxygen was measured by the modified Winkler method, and salinity, temperature, and conductivity with a YSI Model 33-SCT meter. Stream discharge was estimated following Robins and Crawford (1954).

Results

Water quality

High hardness and sulfates and low concentration of heavy metals and suspended solids characterized the effluents before the dam rupture (table 1). Most chemical quality parameters, except dissolved oxygen, water temperature, and pH, increased after the dam rupture but returned to predisturbance levels within 1 week. Low surface flow was continuous but variable (maximum, 8.7 l/s) during the study. Stream physiography and water quality of Pinto Creek was generally similar to that of the discharge channel before May and remained stable throughout the study.

Stream morphometry

Pool and riffle depths were reduced 50% to 90% respectively in May when the effluents (20 l/s) and ore tailings (suspended solids = 4,480 mg/l) innundated and buried the natural substrate (fig. 2). Natural substrate in pool and riffles was covered with ore tailings up to 0.5 m. As a result, the alternating pool-riffle structure with gravel substrate was permanently altered to essentially a long "run" with sandy substrate. Further, deposition of the tailings cemented the substrate by filling interstitial pore spaces and causing a shift of the stream channel within the flood plain. Summer rains scoured the deposits from the substrate and partially restored the stream bed at Stations 1, 2, and 3.

Biota

Two classes of vertebrates and eight orders (five genera) of aquatic invertebrates were found in the waste stream in March 1975, but only six orders (four genera) were collected in July of that year (table 2). Species of Baetidae, Helicopsychidae, Veliidae, Simulidae, and Notonectidae were most commonly collected prior to the tailings pond rupture but in July species of Gerridae, Hydrophilidae and Notonectidae predominated. The thick tailings deposits adversely affected the clinging species of Heptagenidae, Coenagrionidae and Helicopsychidae more than the bottom (Limnephilidae, Baetidae) and water surface (Gerridae, Veliidae) dwellers. Macroinvertebrate diversity was higher at Stations 1, 2, and 3 during the latter part of the study due to the scouring of tailings from the substrate.

Table 1.—Mean physiochemistry of tailings pond effluents in a waste stream for which biotic composition was determined during 1975

Quantity measured	1975 Jan.	Mar.	May	July	Sept.	Nov.	1976 Jan.
pH	7.6	7.6	8.1	8.0	8.2	8.1	8.1
Calcium (Ca)	185	200	206	251	208	175	211
Magnesium (Mg)	21	24	24	32	22	26	12
Sodium (Na)	28	34	143	61	37	29	32
Iron (Fe)	<0.05	<0.05	0.25	0.1	<0.05	<0.05	<0.05
Copper (Cu)	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05
Manganese (Mn)	<0.05	<0.05	0.83	<0.05	<0.05	<0.05	<0.05
Zinc (Zn)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulfate (SO_4)	350	480	800	600	400	200	375
Total suspended solids	0	0	2,300	23	1	0	0
Total alkalinity (mg/l $CaCO_3$)	130	134	204	124	190	180	200
Total hardness (mg/l $CaCO_3$)	465	600	816	764	610	360	245
Mean discharge (l/s)	3.3	4.9	7.0	7.8	5.9	5.9	8.7

A B C

Figure 2.—Substrate of the waste stream before (A) and after (B,C) a large influx of tailings pond wastes.

Table 2.—Biotic composition in Pinto Creek (PC) and in the waste stream (WS) during three representative sampling periods

	March 1975		July 1975		March 1976	
Taxa	**WS**	**PC**	**WS**	**PC**	**WS**	**PC**
Gordiidae						
Gordius sp.	X	X		X		
Hemiptera						
Belostomatidae						
Abedus hebridi	X	X	X	X	X	X
Corrixidae						
Graptocorixa sp.	X	X		X		
Notonectidae						
Notonecta lobata	X	X	X	X	X	X
Notonecta kirbyi	X	X	X	X		X
Notonecta undulata		X		X	X	X
Gerridae						
Gerris remigis	X	X	X	X	X	X
Veliidae						
Rhagovelia sp.	X		X	X	X	X
Mesoveliidae						
Mesovelia mulsanti	X			X	X	X
Ephemeroptera						
Baetidae						
Callibaetis sp.		X		X		X
Baetis spp.	X	X	X	X	X	X
Heptagenidae						
Rhithrogena sp.				X	X	X
Lepidoptera						
Paragyractis sp.		X				X
Coleoptera						
Dytiscidae						
Agabus sp.	X			X		X
Thermonectes marmoratus	X			X		X
Dytiscus sp.	X			X		X
Gyrinidae						
Gyrinus sp.	X	X	X	X	X	X
Hydrophilidae						
Berosus sp.	X	X		X		X
Hydrophilus sp.		X		X	X	X
Diptera						
Culicidae						
Culex sp.	X	X				X
Tipulidae						
Tipulus sp.	X	X				X
Simuliidae						
Simulium sp.	X	X		X		
Tendipedidae						
Tendipes sp.	X	X	X	X	X	X
Tabanidae						
Tabanus sp.	X	X				
Trichoptera						
Limnephilidae						
Limnephilus sp.	X	X			X	X
Helicopsychidae						
Helicopsyche borealis	X	X		X		X
Odonata						
Lestidae						
Lestes cogener		X		X	X	X
Coenagrionidae						
Argia sp.		X		X		
Libellulidae						
Libellula sp.	X	X	X	X	X	X
Gomphidae						
Progomphus sp.	X	X		X		X
Megaloptera						
Corydalidae						
Corydalus cornutus	X	X		X		X

Rana and *Bufo* larva (frogs and toads) and approximately 158 *Agosia chrysogaster* (as determined from the population estimate) inhabited the waste stream before May, but were not collected again until July 1976. At this time surface flow in Pinto Creek near the confluence area was absent. Amphibian larva and *Agosia* were collected throughout the study in Pinto Creek. The number of genera in Pinto Creek was similar to that in the waste stream before May (table 3).

Benthic vegetation was more affected by the wastes than emergent vegetation or riparian species. The tailings deposits buried most benthic vegetative stands; however, partial emergence from the deposits occurred within 7 weeks after the waste influx. There was no discernible toxin damage to any plant species attributable to heavy metals.

Table 3.—Number of genera of invertebrates and vertebrates collected per sampling period in the waste stream and Pinto Creek

Sampling period	Waste stream	Pinto Creek
1975		
Jan.	11	14
March	24	25
May	4	24
July	9	26
Sept.	7	23
Nov.	9	20
1976		
Jan.	7	9
Feb.	8	13
March	14	26

Discussion

Streams polluted by heavy metals and suspended solids typically support less dense and diverse faunas than do unpolluted streams (Savage and Rabe 1973, Ryck 1974, LaBounty et al. 1975). Waste streams conveying undiluted metals and solids to a receiving stream would be expected to support fewer, if any, organisms. The waste stream in this report initially supported a fauna as diverse as that of the larger, less polluted Pinto Creek. However, after a large influx of wastes the biotic composition in the waste stream was reduced.

Changes in effluent quality were variable throughout the period of study and proper evaluation of the chemical factors on the biota was therefore difficult. Nevertheless, the drastic short term increases in suspended solids and the residual effects of the resultant siltation were markedly detrimental to the biota, more so than the increases in heavy metals. Suspended solids as high as 4,480 mg/l (mean = 2,300 mg/l) during the disturbance settled and quickly blanketed the stream bed and buried benthic vegetation and invertebrates. Flow at this time (20 l/s) and subsequently (<8 l/s) was inadequate to completely scour the deposits. As a result, biotic composition in the lower stream area 1 year after the dam rupture was approximately 42% less than that in March 1975. Suspended solids of 40 to 390 mg/l have been reported to reduce invertebrate populations by 25% to 85% (Tebo 1955, Gammon 1970), and inert deposits of only 2 cm have reduced dipteran populations by 50% (Hoak 1959).

The effects of the increases in heavy metals were less noticeable and more difficult to ascertain than those of the suspended solids. However, the short duration of the metals in the water column after the dam rupture, due to probable adsorption or complexing with organic and inorganic substances, may have reduced the toxicity of this pollution to the biota. Adsorption of metals by either muds or humic acids had been reported to reduce metal toxicity (Riemer and Toth 1970, Pagenkopf et al. 1974). In contrast, the insoluble complexed metal compounds, upon settling, served as a metal reservoir for bioaccumulation. Metal residues in invertebrates, aquatic vegetation, fish and sediments collected from the waste stream were significantly higher ($P < 0.05$) than those in similar species collected from unpolluted streams (Lewis unpublished). The effect of these residues on biotic survival was not discernible, however with time it may become more noticeable.

Mean copper (0.1 mg/l) and manganese (0.83 mg/l) concentrations during the disturbance were below acute lethal levels estimated for juvenile *Agosia chrysogaster* in laboratory bioassays (0.88 mg/l copper and 130.0 mg/l manganese); however, the estimated safe copper level of 0.08 mg/l (based on an application factor of 0.01) was exceeded. Metal toxicity to invertebrates has been less investigated than that for fish but based on reported toxicity values it is unlikely that the metal ions in the wastes were acutely toxic. Rhewoldt et al. (1973) determined 96-hour lethal levels for damselflies (4.6-10.0 mg/l copper), caddisflies (6-12 mg/l) and midges (0.03-0.65 mg/l). Warnick and Bell (1969) observed mayflies and caddisflies to be resistant to 64 mg/l of copper and zinc.

Unpolluted desert streams support more diverse aquatic communities than do mine-polluted streams that are susceptible to ever-changing effluent quality and quantity. The ability of such "waste" streams to support permanent aquatic life with long life cycles is marginal. Therefore, the primary biological significance of these streams may be to serve as temporary habitat for larval amphibians, migratory invertebrates and

invertebrates with short aquatic life cycles. Finally, waste streams also support riparian communities; however, the permanence of these communities depends upon the potential toxicity of the metal-enriched sediments and water. The short duration of this study was inadequate to determine the presence of this toxicity.

Literature Cited

American Public Health Association. 1971. Standard methods for the examination of water and wastewater. 13th ed. New York, N.Y. 874 p.

Gammon, J. R. 1970. Effect of inorganic sediment on stream biota. U.S. Environ. Prot. Agency Rep. U.S. Gov. Print. Off., Wash., D.C. 119 p.

Hoak, R. D. 1959. Physical and chemical behavior of suspended solids. Sew. Ind. Wastes 31:1401-1408.

LaBounty, J., J. J. Satoris, L. D. Klein, E. F. Monk, and H. A. Salman. 1975. Assessment of heavy metals pollution in the upper Arkansas River of Colorado. Bur. of Rec. REC-ERC-75-5. Denver, Colo. 120 p.

Pagenkopf, G. K., R. C. Russo, and R. V. Thurston. 1974. Effects of complexation on toxicity of copper to fishes. J. Fish. Res. Bd. Canada 31:462-465.

Rehwoldt, R., L. Lasko, C. Shaw, and E. Wirhowski. 1973. The acute toxicity of some heavy metal ions toward benthic organisms. Bull. Environ. Contam. Toxicol. 10:291-294.

Riemer, D. N., and S. J. Toth. 1970. Adsorption of copper by clay minerals, humic acids, and bottom muds. J. Amer. Water Works Assoc. 62:195-197.

Robins, C., and R. W. Crawford. 1954. A short accurate method for estimating the volume of stream flow. J. Wildl. Manage. 18:363-369.

Ryck, F. 1974. Water quality survey of the Southeast Ozark mining area 1965-1971. Miss. Dep. of Conserv., Aq. Ser. No. 10. 28 p.

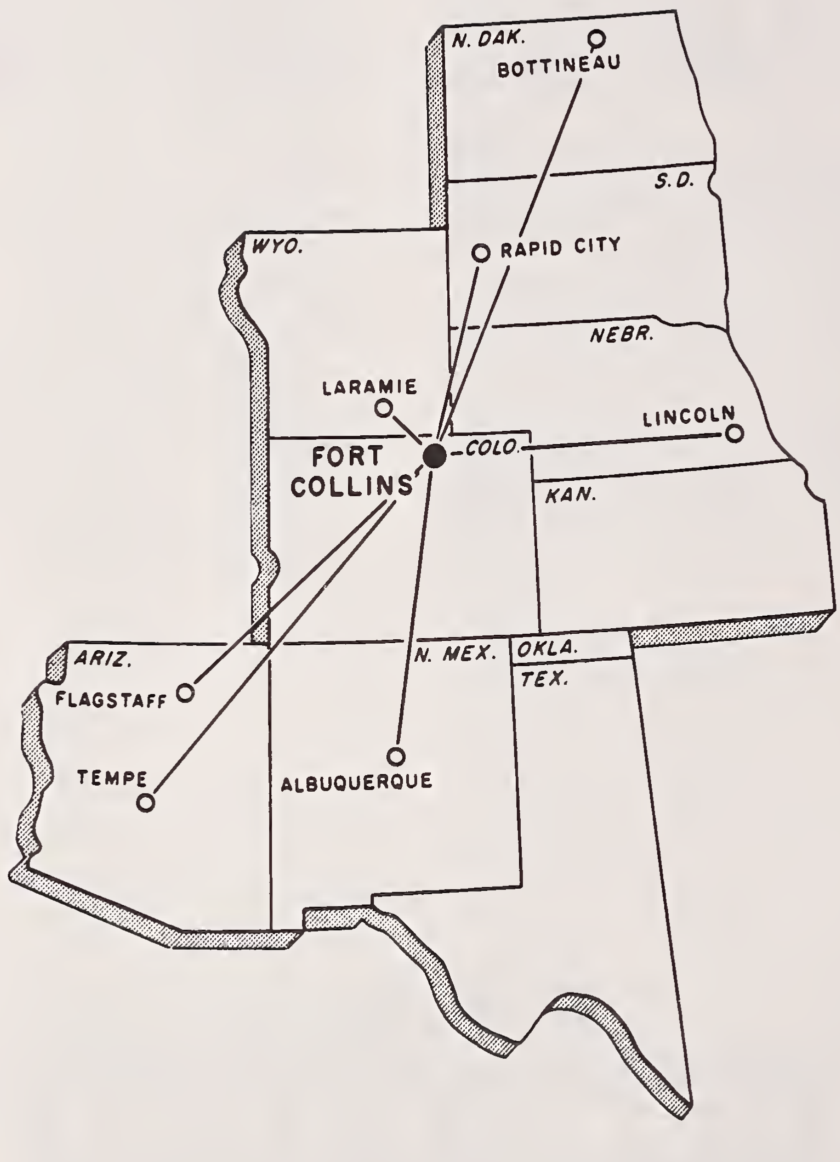
Savage, N. L., and F. N. Rabe. 1973. The effects of mine and domestic wastes on macroinvertebrate structure in Coeur d' Alene River. Northwest Sci. 47:159-167.

Tebo, L. B. 1955. Effects of siltation resulting from improper logging on the bottom fauna of a small trout stream in the southern Appalachians. Prog. Fish-Cult. 17:64-70.

Warnick, S. L., and H. L. Bell. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. J. Water Pollut. Cont. Fed. 4:280-285.

SURFACE ENVIRONMENT & MINING
SEAM
PROGRAM

Agriculture—CSU, Fort Collins


N. DAK.
BOTTINEAU
S.D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT
COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE